

***Oxychilus geminus* sp. nov., a new species from mainland Sicily
morphologically similar to *Oxychilus denatale* (L. Pfeiffer, 1856)
(Gastropoda: Oxychilidae)**

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Abstract. A new species of *Oxychilus* Fitzinger, 1833 is described from Montagna Longa near Carini, north-western Sicily. *Oxychilus geminus* sp. nov. shows a close morphological resemblance to *O. denatale* (L. Pfeiffer, 1856) from Marettimo Island, the species for which Monterosato (1892) introduced the genus-group name *Hyalofusca*. The new species shares with *O. denatale* a depressed, tightly coiled, opaque-silky and finely granulate shell, a well-developed vaginal gland, a very short flagellum, a conspicuous penial sheath, and a broadly comparable pattern of internal penial ornamentation. *Oxychilus geminus* sp. nov. is nevertheless clearly distinguished from *O. denatale* by a coherent combination of conchological and genital characters, including its substantially smaller shell, fewer whorls, massive and broadly rounded peripheral keel forming a distinct basal step, proportionally wider umbilicus, short and conical duct of the bursa copulatrix, much shorter epiphallus, proximal penis shorter than the distal penis, conspicuous constriction between the two penial regions, and a thin penial sheath restricted to the distal portion of the distal penis. The morphological resemblance between the two species does not, however, provide sufficient evidence for their inclusion in a natural group corresponding to *Hyalofusca*. None of the shared characters can presently be demonstrated to represent an exclusive synapomorphy, and the systematic validity and morphological limits of *Hyalofusca* itself remain unresolved.

Key words. Western Mediterranean, polygyrate shell, shell microsculpture, distal genitalia, penial sheath, epiphallus morphology, subgeneric reassessment

ZooBank registration. urn:lsid:zoobank.org:pub:ADDCE299-CD6A-4BA0-B260-0F045222D7C3

DOI. <https://doi.org/10.61733/jconch/4590>

INTRODUCTION

The genus-group name *Hyalofusca* Monterosato, 1892 was introduced for *Helix denatale* L. Pfeiffer, 1856, an endemic species from Marettimo Island in the Aegadian Archipelago. Monterosato's classification of the Sicilian polygyrate oxychilids was based almost entirely on shell appearance and did not include anatomical evidence or a formal comparative framework capable of demonstrating natural relationships among the taxa involved.

The name *Hyalofusca* was subsequently largely overlooked for several decades, until it was revived by Riedel (1973), who treated it as a valid subgenus of *Oxychilus*.

Riedel recognised two principal historical and biogeographical components among the Sicilian polygyrate oxychilids. One comprised *O. denatale*, referred to *Hyalofusca*; the other was represented by taxa assigned to *Hyalocornea* Monterosato, 1892, including *Oxychilus canini* (Benoit, 1843), *O. alicurensis* (Benoit, 1857), *O. egadiensis* Riedel, 1973, and *O. nortoni* (Calcara, 1843), which he interpreted as forming an east–west morphological sequence. Riedel's concept of *Hyalocornea* was primarily conchological and biogeographical rather than based on a distinctive genital ground plan. He noted that the external genital morphology and internal penial ornamentation of the species examined did not differ fundamentally from those of *Oxychilus* s. str. and

consequently regarded *Hyalocornea* as closely allied to the nominotypical subgenus and only weakly differentiated at subgeneric rank. Its recognition was based mainly on the depressed shell with numerous tightly coiled whorls and on the geographical coherence of the Sicilian and circum-Sicilian taxa assigned to it.

By contrast, Riedel (1973) considered *O. denatale* to represent a more isolated morphological entity among European *Oxychilus* and tentatively suggested possible affinities with North African Oxychilinae, particularly *Allogenes* Gude, 1911. Riedel (1980) subsequently retained both *Hyalocornea* and *Hyalofusca* as subgenera of *Oxychilus*. He regarded the anatomy of *Hyalocornea* as essentially identical to that of *Oxychilus s. str.*, whereas the anatomical characterisation of *Hyalofusca* necessarily remained based on *O. denatale* alone. Among the features emphasised were a very long, slender penis divided into unequal proximal and distal regions, a very long epiphallus, a very short terminal flagellum, and a large perivaginal gland. Thus, Riedel (1980) essentially maintained the systematic framework proposed in 1973, without providing independent evidence for the phylogenetic validity of either group. Schileyko (2003), in his largely compilative treatment of terrestrial pulmonates, retained Riedel's interpretation of both *Hyalofusca* and *Hyalocornea* with little modification.

The original basis of Monterosato's genus-group taxa should, however, be regarded with considerable caution. His arrangement of the Sicilian polygyrate forms relied almost exclusively on superficial shell characters. He separated forms described as "corneous" from those regarded as "shining", assigning them respectively to *Hyalocornea* and *Hyalofulgida*, whereas *O. denatale* was separated under the name *Hyalofusca*. No anatomical evidence or explicit set of diagnostic characters capable of demonstrating natural relationships among these groups was provided. Under a modern systematic perspective, such characters alone have limited value for establishing genus-group boundaries, particularly in Oxychilinae, where shell convergence is widespread. The situation is further complicated by *Hyalofulgida*, which included, among other forms, Monterosato's *aegusina* from Favignana, a taxon whose identity and systematic position remain obscure.

The subsequent recognition of Monterosato's genus-group taxa as distinct systematic units therefore represents a later interpretation of Monterosato's nomenclature rather than a classification demonstrably supported by the original diagnostic evidence.

Manganelli *et al.* (2007), following a detailed modern redescription of *O. denatale*, explicitly concluded that the

phylogenetic significance of the observed characters could not be established. They therefore postponed assessment of the relationships of *O. denatale* and of the status of *Hyalofusca* until broader comparative information on Sicilian *Oxychilus* became available. We consider this cautious position still appropriate. Although the present study substantially increases the comparative morphological information available, it was designed primarily to describe and delimit a new species and does not provide a sufficiently comprehensive dataset to test the validity, limits or phylogenetic relationships of the historical genus-group taxa introduced by Monterosato.

Manganelli *et al.* (2007) therefore provide the principal modern comparative framework for *O. denatale*, including shell microsculpture, distal genital anatomy, and a critical discussion of its possible relationships. Their study is used here primarily to distinguish characters that may be specific to *O. denatale* from those shared with the new taxon, rather than as a basis for accepting any particular subgeneric classification.

During field investigations in north-western Sicily, undertaken as part of broader research on the terrestrial gastropod fauna of the island, we discovered an unusual population near Carini, Palermo Province. Its markedly depressed shell with numerous tightly coiled whorls was broadly reminiscent of the Sicilian polygyrate oxychilids but did not, by itself, permit a reliable systematic assignment. The unusual shell architecture also showed superficial similarities to that of *Alzonula* Giusti, 1968, an insular taxon from Montecristo, and the strongly depressed profile and peripheral configuration initially prompted consideration of affinities with other morphologically convergent groups. These comparisons emphasised the ambiguity of the conchological evidence and the need for anatomical investigation.

Examination of the distal genitalia revealed substantial morphological similarity to *O. denatale*. In particular, the new taxon shares with *O. denatale* a very short flagellum, a conspicuous penial sheath, a well-developed vaginal gland, and a broadly comparable pattern of internal penial ornamentation. At the same time, it differs markedly in several shell and genital characters, including shell size, number of whorls, configuration of the peripheral keel, relative width of the umbilicus, length and shape of the duct of the bursa copulatrix, epiphallus length, proportions of the proximal and distal penis, and extent of the penial sheath. These similarities and differences form the basis of the comparative analysis presented below. They are not interpreted here as evidence for formal assignment of the new species to *Hyalofusca*, whose morphological coherence and systematic validity remain unresolved.

MATERIALS AND METHODS

The present study is based on targeted field investigations carried out in north-western Sicily within the framework of broader research on terrestrial gastropod diversity. During these surveys, a population attributable to *Oxychilus* was discovered on the slopes of Montagna Longa, near Carini (Palermo Province). Field investigations were initially conducted at the discovery site and subsequently expanded outwards from this point, at increasing distances and in different directions across the surrounding limestone sectors, in order to assess the spatial distribution of the species and verify its persistence in the area. Despite repeated and spatially structured surveys, the species has so far been confirmed exclusively from the type locality.

Because the actual extent of the species' distribution remains unknown and to minimise any potential impact on the natural population, collecting of live material was deliberately restricted to the minimum required for anatomical study. Consequently, only five adult living specimens were collected, and no additional live individuals were removed from the population.

These five alcohol-preserved specimens were photographed and examined for both qualitative and quantitative shell characters prior to dissection, allowing direct correspondence between shell morphology and genital anatomy. To improve the assessment of shell variability without further affecting the living population, the conchological dataset was supplemented with 15 additional adult empty shells collected at the type locality, resulting in a total sample of 20 shells for shell morphological analyses.

The genitalia of all five specimens were dissected under a Zeiss Stemi 305 stereomicroscope to document both external and internal genital morphology and to assess intraspecific anatomical variability. Genital investigations were performed on organs gently extended without artificial stretching. The following structures were investigated: vagina, duct of the bursa copulatrix, bursa copulatrix, epiphallus, flagellum, proximal penis, distal penis, and penial sheath. Boundaries between penial regions were identified from external constrictions and changes in internal ornamentation.

Shells were photographed using a Canon EOS digital camera mounted on a micrometric sliding stage. Image stacks were combined with Helicon Focus to obtain fully focused images, from which all measurements were taken. Shell measurements were taken from calibrated digital images using ImageJ (v. 1.54r) to the nearest 0.01 mm. Quantitative shell morphology was documented using a

standardised set of linear measurements designed to capture overall shell shape and proportions. The selected variables include: shell diameter, shell height, umbilicus diameter, and number of whorls.

Qualitative shell characters, with particular emphasis on overall shell architecture and microsculpture, were evaluated independently from the quantitative morphometric analyses to assess intra-population variability and avoid overinterpretation of rare or aberrant shell morphologies. Anatomical terminology and the subdivision of the penis into proximal and distal portions follow Manganelli *et al.* (2007), with modifications required by the presence of the conspicuous constriction observed in the new species.

Comparisons with the remaining Sicilian representatives of *Oxychilidae* followed the diagnoses and comparative framework provided by Manganelli *et al.* (2007) and the current MolluscaBase checklist (Bank & Neubert 2017).

The radula was not examined in the available material. Comparisons were therefore based on shell morphology and distal genital anatomy.

Study area and geological setting

Montagna Longa (Fig. 1) is a massif composed of Mesozoic–Cenozoic carbonate rocks belonging to the Panormide Unit, a carbonate platform succession forming the northernmost sector of the Palermo Mountains in north-western Sicily. This area is part of the Sicilian Fold-and-Thrust Belt, a complex tectonic domain developed during the convergence between the African and European plates, linking the African Maghrebides with the subduction-related Calabrian Arc and the southern Apennines (Catalano *et al.* 2013). The geological framework is dominated by thick Mesozoic and Cenozoic carbonate successions, consisting mainly of platform limestones and dolostones subsequently deformed by compressional tectonics and locally modified by erosion and karstification. These geological processes have produced a rugged landscape characterised by steep rocky slopes, cliffs, fissured limestone outcrops, sinkholes, and a well-developed karstic microrelief. The terrain is further compartmentalised by rocky ridges, deeply incised valleys, and recent anthropogenic habitat fragmentation, resulting in a mosaic of partially isolated habitat patches. These carbonate substrates provide a wide variety of microhabitats, including shaded crevices, rock fissures, scree, and localised humid refugia, which offer favourable ecological conditions for calcicolous terrestrial gastropods. In addition, the high permeability of the carbonate rocks, together with the pronounced topographic and microclimatic heterogeneity, contributes to the persistence of moisture-retaining habi-

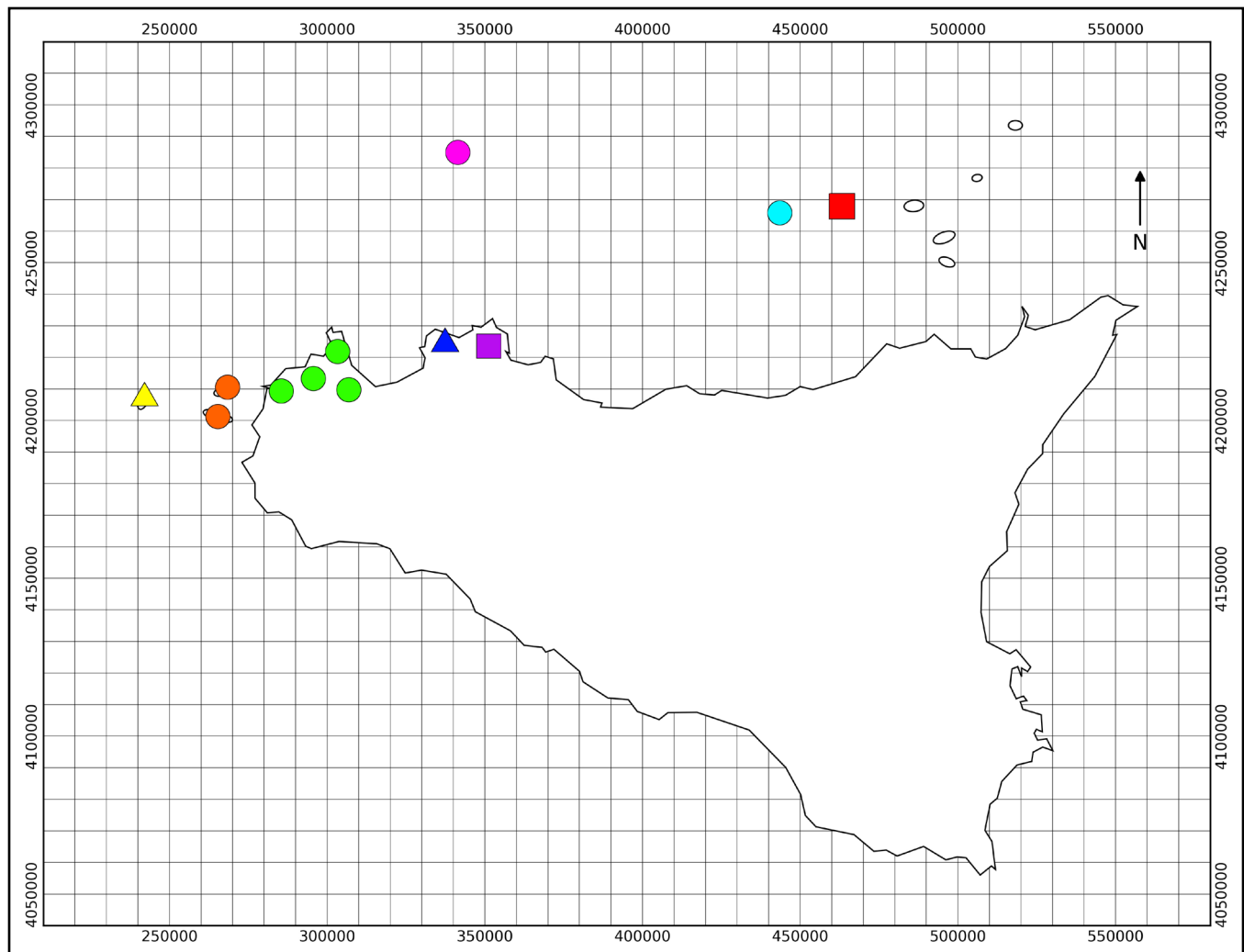


Figure 1. Geographic distribution of *Oxychilus* spp. in north-western Sicily (Palermo and Trapani provinces). Orange circle: *O. egadiensis* (Favignana and Levanzo); green circle: *O. canini* (Trapani area, from Castellammare del Golfo to Mount Erice); violet circle: *O. nortoni* (Ustica); light blue circle: *O. alicurensis* (Alicudi); yellow triangle: *O. denatale* (Marettimo); blue triangle: *O. geminus* sp. nov. (Montagna Longa); violet square: *O. cf. fuscus* (Palermo area); red square *O. lagrecai* (Filicudi).

tats that support a rich and often highly localised land-snail fauna. The marked structural complexity of the landscape is also likely to reduce connectivity among populations of low-dispersal terrestrial gastropods, thereby promoting fine-scale geographic isolation, local endemism, and speciation.

The occurrence on mainland western Sicily of a species showing substantial morphological similarity to *O. denatale* from Marettimo is potentially relevant from a biogeographical perspective. This distribution could be compatible with either the persistence of a formerly wider morphological lineage or a more complex history of differentiation in western Sicily and the Aegean Islands. The geological continuity of carbonate substrates in western Sicily provides a plausible spatial framework for the long-term persistence of localised

terrestrial gastropod populations, although the available evidence does not presently allow a specific historical scenario to be favoured.

Multivariate morphometric analyses

To explore the morphometric relationships among western Sicilian *Oxychilus* taxa, multivariate analyses were performed using four shell measurements: shell diameter (SD), shell height (SH), umbilicus diameter (UD), and number of whorls (NW). The dataset comprised eight species: *Oxychilus geminus* sp. nov., *O. denatale* (L. Pfeiffer, 1856), *O. alicurensis* (Benoit, 1857), *O. canini* (Benoit, 1843), *O. egadiensis* A. Riedel, 1973, *O. nortoni* (Calcara, 1843), *O. lagrecai* Giusti, 1973 and *O. cf. fuscus* (Rossmässler, 1838),

each represented by 20 specimens, for a total sample of 160 specimens. Prior to analysis, all variables were standardised to zero mean and unit variance (z-scores). Principal Component Analysis (PCA) was used as an exploratory ordination method to visualise the distribution of specimens in multivariate morphospace. Subsequently, Linear Discriminant Analysis (LDA) was performed to evaluate the discriminatory power of the shell measurements among the predefined species. Classification performance was assessed using leave-one-out cross-validation (LOOCV).

Abbreviations

A atrium, AOO area of occupancy, BC bursa copulatrix, CDW Willy De Mattia collection, CR Agatino Reitano collection, DBC duct of bursa copulatrix, DP distal penis, F flagellum, FHD first hermaphrodite duct, FO free oviduct, MSS superficial subterranean environment, NHMW Natural History Museum Wien, OS ovispermiduct, PP proximal penis, RM retractor muscle, SD shell diameter, SH shell height, STD standard deviation, UD umbilicus diameter, V vagina, VD vas deferens, VG vaginal gland, NW number of whorls.

SYSTEMATICS

Family Oxychilidae P. Hesse, 1927

Subfamily Oxychilinae

Genus *Oxychilus* Fitzinger, 1833

Oxychilus geminus sp. nov.

Figures 2–4

ZooBank registration. urn:lsid:zoobank.org:act:4F5B11CE-63B4-4624-89A1-BABF35484D7D

Type locality. C.da Guardiola, Montagna Longa, Carini, Palermo, Italy, 38°07'46.17"N 013°09'15.40"E, 555 m a.s.l., Willy De Mattia leg., 6 March 2025.

Type material. Holotype: NHMW-ZOO-MO-114178.

Paratypes: NHMW-ZOO-MO-114179, 1 alcohol-preserved specimen; 3 alcohol-preserved specimens + 12 dry shells CDW; 10 dry shells CR.

Diagnosis. A small species of *Oxychilus*, with shell diameter 8.2–9.9 mm; shell strongly depressed, opaque-silky and finely granulate, with 4.70–5.50 slowly increasing whorls; body whorl strongly compressed and bearing a massive, broadly rounded peripheral keel forming a distinct basal step; umbilicus 22–25% of shell diameter. Duct of bursa copulatrix short and conical; epiphallus slightly longer than

the proximal penis and much shorter than in *O. denatale*; flagellum very short, broad, and blunt; proximal penis shorter than distal penis and separated from it by a conspicuous constriction; penial sheath thin and restricted to the distal portion of the distal penis.

Description. Body. Animal very pale, diaphanous, almost transparent in general appearance. Foot white, extremely slender and elongate. Dorsal surface very weakly bluish, the colour diffuse and never forming dark patches or distinct pigmentation. Pallial cavity visible through the body whorl. Mantle without spots or other pigment markings. Ocular spots extremely faint. The general appearance is therefore much paler and more translucent than in strongly pigmented Oxychilinae species, and the animal has a delicate, nearly colourless aspect when alive or freshly preserved.

Shell (Fig. 2). Dextral, medium-small, depressed, discoidal but rather square in outline, extremely thin and fragile, opaque-sericeous, very pale yellowish when fresh, paler and slightly opalescent below. Whorls 4.70–5.50, slowly and regularly increasing in size; spire flat to slightly concave, with the earliest whorls slightly raised at the centre. First whorls transparent and glossy. Protoconch apparently almost smooth at low magnification, with only very weak spiral striation, sometimes almost invisible. Teleoconch with both radial and spiral sculpture. Radial sculpture formed by fine growth striae, more evident on the earliest teleoconch whorls and weaker on the upper surface of the body whorl, although still visible. Spiral sculpture more evident on the first whorls and especially in the parasutural areas; it becomes weaker on the dorsal surface of the body whorl but remains clearly visible on the basal surface. The crossing of these fine radial and spiral elements gives the shell a finely granulate appearance over most of the surface.

Sutures deep, strongly impressed and clearly marked throughout the shell; the adjacent shell surface is distinctly raised, producing a slightly shouldered or convex appearance of the upper whorl surface. Last whorl opaque, strongly compressed and provided with a conspicuous peripheral keel. The keel is very strong, massive and rounded, not sharp or blade-like. On the basal side it forms a marked step, clearly separating the peripheral keel from the lower surface of the body whorl. Final part of last whorl, near the aperture, not descending. Aperture very oblique, markedly rhomboidal; owing to the strong keel, the outer part of the aperture appears almost lanceolate. Peristome interrupted, simple, not reflected, with only very slight thickening in fully mature specimens. Umbilicus wide, approximately one quarter of maximum shell diameter.

Measurements (range, mean $\pm$ STD, mm; $n = 20$): shell diameter 8.20–9.90, 9.06 ± 0.51 ; shell height 2.80–3.50, 3.10 ± 0.19 ; umbilicus diameter: 1.90–2.30, 2.13 ± 0.14 ; number of whorls: 4.70–5.50, 5.11 ± 0.25 . Shell diameter/shell height ratio: 2.83–3.00, 2.92 ± 0.04 . Umbilicus diameter/shell diameter ratio: 0.22–0.25, 0.235 ± 0.008 .

Genital anatomy. Only distal genitalia are described here from sexually mature adult specimens (Figs 3, 4).

Female distal genitalia include free oviduct, bursa copulatrix with its duct, and vagina. Vagina long; approximately half of its length is enveloped by an evident spongy glandular tissue forming the vaginal gland. Distal vagina comparatively broad. Duct of bursa copulatrix short, conical, about 2.3 mm long, passing into a short oval bursa copulatrix about 2.2 mm long. The transition between duct and bursa is clearly recognisable. The bursa is therefore not simply the swollen end of a long cylindrical duct, but a distinct oval structure connected to a short tapering duct.

Male distal genitalia include vas deferens, epiphallus, and penial complex. Epiphallus moderately long (about 5.4 mm), slender, cylindrical, and of nearly constant calibre for most of its length; it is not swollen, not flared, and becomes only moderately twisted before attaching to the penial sheath/distal penial region. Flagellum very short (c. 1.2 mm), broad and blunt at apex, where the penial retractor muscle inserts. Penis distinctly divided into proximal and distal portions by a narrow region forming a conspicuous bottle-neck structure, situated rather proximally. Proximal penis about 4.2 mm long, shorter than distal penis (c. 6.6 mm; PP/DP c. 0.6). Proximal penis wide for most of its course, except at the bottle-neck structure. Distal penis broad, becoming still wider towards the genital atrium, where it reaches its maximum calibre. Distal part of distal penis enveloped by a thin, transparent penial sheath. The sheath does not cover the entire distal penis, but only approximately its distal third. Genital atrium wide and robust.

Internal walls of proximal penis with papillae surrounding the epiphallar opening and then arranged in about seven or eight longitudinal rows. Papillae very numerous, variable in size and shape, polygonal, pyramidal, or conical according to their position. Towards the bottle-neck structure, these rows pass into longitudinal pleats. Internal walls of distal penis with five or six evident continuous pleats derived from the papillar rows. In the proximal part of the distal penis the pleats are very irregular, sometimes branched and interconnected; distally, towards the genital atrium, they become progressively more regular and assume the appearance of smooth, conspicuous longitudinal folds.

Etymology. The specific epithet *geminus*, from the Latin *geminus* (“twin”), refers to the striking morphological resemblance between the new species and *O. denatale* from Maretimo Island, particularly in overall shell architecture and several features of the distal genital anatomy. The name emphasises this morphological parallelism rather than implying a demonstrated phylogenetic relationship.

Remarks. The closest morphological comparison of *O. geminus* sp. nov. is with *O. denatale*, the species for which Monterosato (1892) introduced *Hyalofusca*. The two taxa share a distinctive combination of shell and distal genital characters discussed below. Nevertheless, none of these features can presently be demonstrated to constitute an exclusive synapomorphy supporting *Hyalofusca* as a natural group. We therefore refrain from formally assigning the new species to a subgenus. Its close morphological association with *O. denatale* is recognised here without implying the systematic validity or monophyly of *Hyalofusca*.

Differential diagnosis. The new species is most closely comparable morphologically with *O. denatale* from Maretimo Island (Figs 5, 6, Table 1), the species for which Monterosato (1892) introduced the genus-group name *Hyalofusca*. The two species share a distinctive combination of shell and distal genital characters, including a depressed and tightly coiled shell, a very short flagellum, a conspicuous penial sheath, papillose proximal penial ornamentation, and a well-developed vaginal gland. They differ, however, in a coherent set of conchological and anatomical characters, detailed below.

Concerning the shell, *O. geminus* sp. nov. is markedly smaller than *O. denatale*. In the available material, shell diameter is 8.20–9.90 mm, whereas *O. denatale* reaches 11.5–14.2 mm in the examined comparative material. The new species also has fewer whorls (4.70–5.50) than *O. denatale* (5.63–6.63) and is therefore less polygyrate. The shell of *O. denatale* is discoidal and opaque-sericeous, with the last whorl more or less angled and slightly descending and flared near the aperture. By contrast, *O. geminus* sp. nov. has a much stronger and broader peripheral keel, massive and rounded rather than simply angled, and forming a distinct basal step. The last whorl does not descend or flare near the aperture. This configuration produces a markedly rhomboidal, almost lanceolate aperture, a feature not developed to the same degree in *O. denatale*.

As regards shell microsculpture, both species have an opaque-sericeous surface with fine sculpture, but *O. geminus* sp. nov. shows a clearer combination of radial growth striae and spiral elements, the latter especially evident on the first

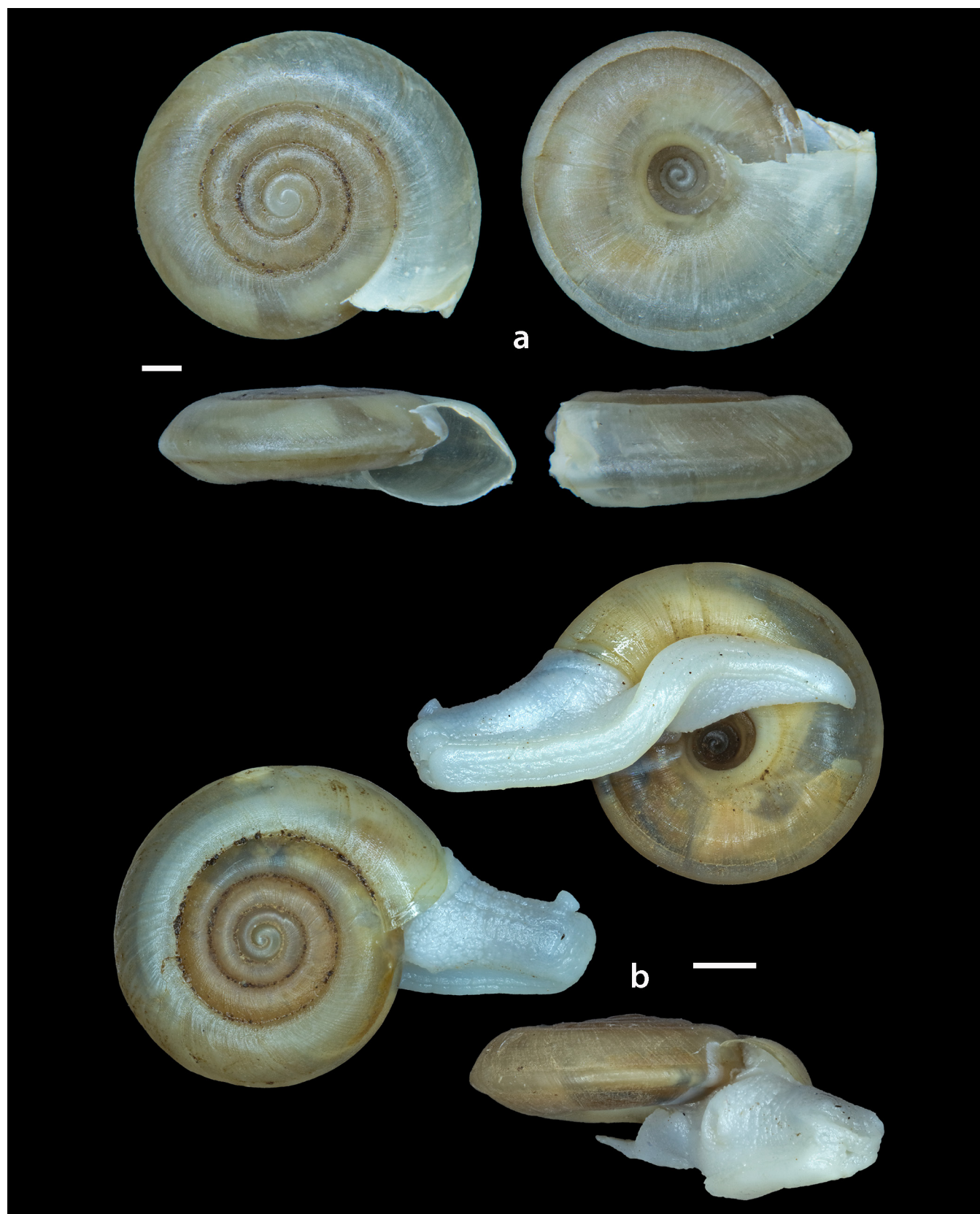


Figure 2. Shells of *Oxychilus geminus* sp. nov. from C.da Guardiola, Montagna Longa, Carini, Palermo, Italy. **a**, holotype NHMW-ZOO-MO-114178. **b**, paratype NHMW-ZOO-MO-114179_1. Scale bars: 1 mm.

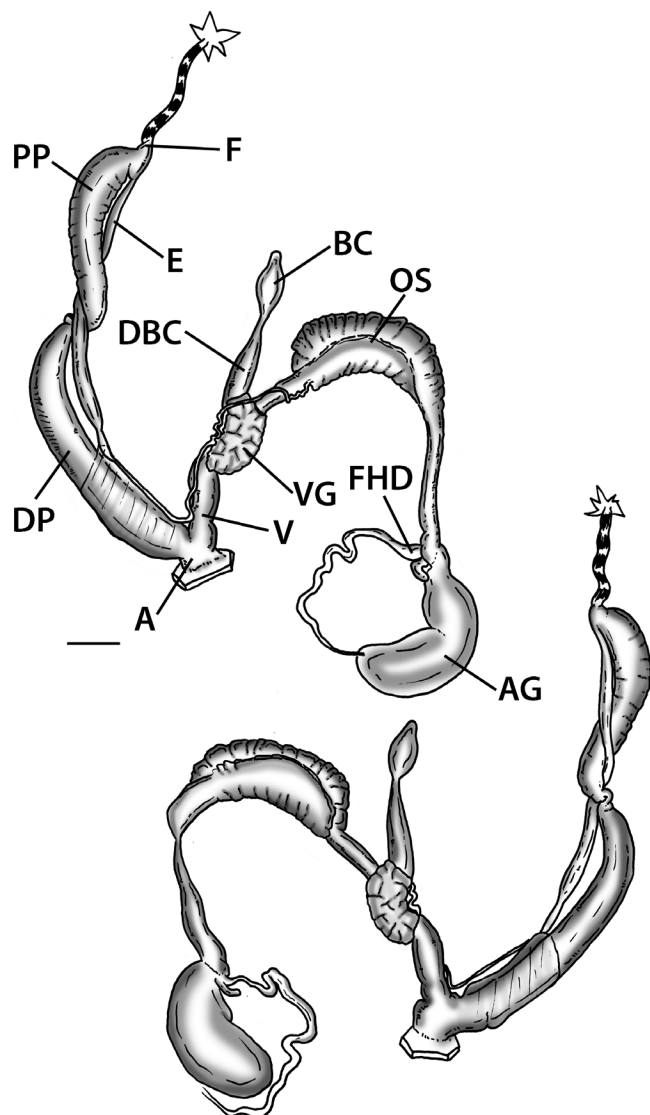


Figure 3. Distal genitalia (gonads excluded) of *Oxychilus geminus* sp. nov. from C.da Guardiola, Montagna Longa, Carini, Palermo, Italy. Holotype NHMW-ZOO-MO-114178. Scale bar: 1 mm.

whorls, in the parasutural regions and on the basal surface of the body whorl. In *O. denatale*, the granulate surface results from crossing spiral and transverse furrows, often producing tiny squares bearing globular reliefs; in *O. geminus* sp. nov., the protoconch appears almost smooth at low magnification and the granulate sculpture is finer and more delicate. Thus, at the magnifications used in the present study, the surface sculpture of *O. geminus* appears finer and less regularly reticulate than that illustrated by Manganelli *et al.* (2007) for *O. denatale*. This difference should nevertheless be regarded as provisional because the shell of the new species was not examined by scanning electron microscopy.

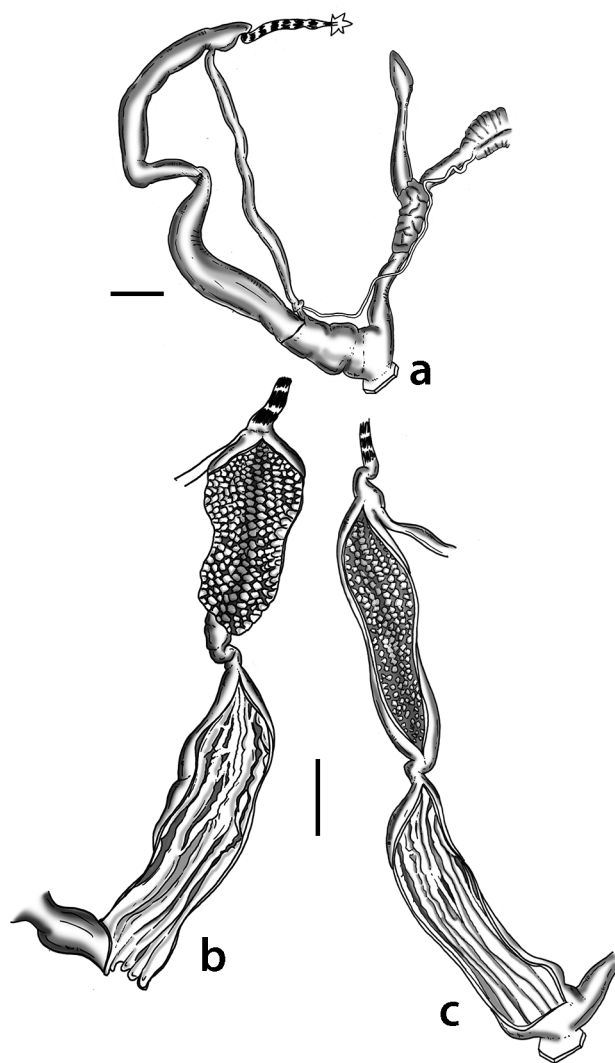


Figure 4. *Oxychilus geminus* sp. nov. from C.da Guardiola, Montagna Longa, Carini, Palermo, Italy. **a**, distal genitalia of the paratype NHMW-ZOO-MO-114179_1. **b**, inner male genitalia of the holotype NHMW-ZOO-MO-114178. **c**, inner male genitalia of paratype NHMW-ZOO-MO-114179_1. Scale bars: 1 mm.

The umbilicus of *O. geminus* sp. nov. is proportionally wider, corresponding to approximately 22–25% of maximum shell diameter, whereas in *O. denatale* it represents approximately 16.7–20%. The shell is also strongly depressed in *O. geminus* sp. nov. (SD/SH 2.83–3.00, mean 2.92), with a low, angular profile strongly influenced by the massive peripheral keel.

In *O. geminus* sp. nov., the vaginal gland occupies approximately half the length of the vagina and the duct of the bursa copulatrix is short and conical (approximately 2.3 mm), passing into a short oval bursa (approximately 2.2 mm). In *O. denatale*, the duct of the bursa copulatrix is cylindrical



Figure 5. *Oxychilus denatale* L. Pfeiffer, 1856 from Case Romane, Marettimo, Trapani, Italy. Scale bar: 1 mm.

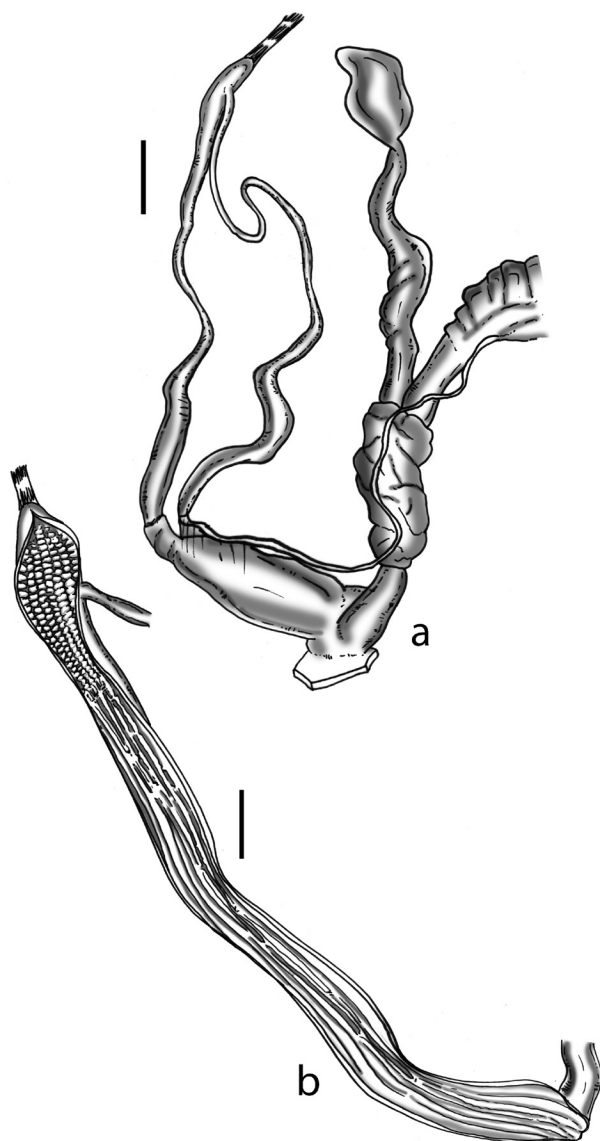


Figure 6. *Oxychilus denatale* L. Pfeiffer, 1856 from Case Romane, Marettimo, Trapani, Italy. **a**, distal genitalia. **b**, inner male genitalia. Scale bars: 1 mm.

and comparatively long (5.4 mm), and the vaginal gland was described as a long glandular muff. The female distal genitalia of the new species therefore differ especially in the much shorter bursal duct and the more abruptly defined transition between duct and bursa.

The strongest diagnostic differences concern the penial complex. In *O. denatale*, the epiphallus is extraordinarily long (16.3 mm) and much longer than the penis, whereas in *O. geminus* sp. nov. it is only moderately long (approximately 5.4 mm), slender and nearly cylindrical. The flagellum is very short and broad in both species.

The relative proportions of the penial regions are reversed. In *O. denatale*, the proximal penis is much longer than the distal penis (PP/DP approximately 3.3), whereas in *O. geminus* sp. nov. the proximal penis is shorter than the distal penis (PP/DP approximately 0.6). This represents one of the most conspicuous anatomical differences between the two species.

Differences in absolute organ length must be interpreted cautiously because *O. geminus* sp. nov. is substantially smaller than *O. denatale*. Nevertheless, the epiphallus remains proportionally much shorter in the new species: E/SD is approximately 0.60 in *O. geminus* sp. nov., compared with approximately 1.24 in the mature *O. denatale* measured by Manganelli *et al.* (2007). The reversed PP/DP ratio and the markedly different extent of the penial sheath are independent of differences in overall shell size and therefore constitute more robust diagnostic characters.

In *O. denatale*, the distal penis is entirely enveloped by a long and extraordinarily thick penial sheath. In *O. geminus* sp. nov., the penial sheath is thin, transparent and restricted to approximately the distal third of the distal penis. The boundary between the proximal and distal penial regions is also situated more proximally in *O. geminus* sp. nov. and forms a distinct bottle-neck structure, whereas *O. denatale* lacks a comparable bottle-neck structure. The extent and configuration of the penial sheath and the morphology of the transition between the two penial regions therefore provide clear anatomical distinctions between the two species.

Concerning the internal penial ornamentation, both species have papillae surrounding the epiphallar opening and longitudinal rows of papillae that pass distally into pleats. In *O. denatale*, the proximal penis has eight or nine rows of papillae, followed by nine or 10 fine continuous pleats and finally six or seven larger pleats. In *O. geminus* sp. nov., the proximal penis has approximately 7 or 8 papillar rows and the distal penis has 5–6 main pleats, which are irregular, branched and interconnected proximally, becoming smoother and longitudinal towards the atrium. The lower number of pleats, their irregular proximal arrangement and their transition in correspondence with the bottle-neck structure further differentiate the new species.

The radula was not examined in *O. geminus* sp. nov. and therefore cannot presently be included in the comparison with *O. denatale* or other Sicilian *Oxychilus*. Manganelli *et al.* (2007) included the long mesocone of the central tooth among the characters supporting the placement of *O. denatale* in *Oxychilus*, while Riedel (1973) also employed radular morphology in his comparisons of Sicilian oxychilines. Radular evidence should therefore be incorporated into future

Table 1. Comparative diagnostic characters distinguishing *Oxychilus geminus* sp. nov. from *Oxychilus denatale* (L. Pfeiffer, 1856). All character states and measurements reported here were newly obtained from specimens examined in the present study and were not compiled from previous literature. The comparison summarises the principal differences in shell morphology, proportions, and distal genital anatomy, including the configuration of the penial complex and internal penial ornamentation. The anatomical features observed in the newly dissected specimen of *O. denatale* are fully consistent with the previous descriptions and illustrations provided by Riedel (1973) and Manganelli *et al.* (2007).

Character	<i>O. geminus</i> sp. nov. <i>n</i> = 5 (mature alcohol-preserved) + 15 (dry shells)	<i>O. denatale</i> <i>n</i> = 2 (mature) + 17 dry shells + 1 (full grown shell and immature genital anatomy)
Shell diameter	8.20–9.90 mm	11.50–14.20 mm
Number of whorls	4.70–5.50	5.63–6.63
Last-whorl periphery	Massive, broadly rounded keel forming a distinct basal step	More or less angular, without a comparable massive keel
Last whorl near aperture	Not descending or flared	Slightly descending and more or less flared
Aperture	Strongly rhomboidal, outer portion almost lanceolate	Oval to rhomboidal
Umbilicus/SD	0.22–0.25	0.17–0.20
Duct of bursa copulatrix	Short, conical, approximately 2.3 mm	Cylindrical, comparatively long, 5.4 mm
Epiphallus	Approximately 5.4 mm; E/SD $\approx$ 0.60	16.3 mm; E/SD $\approx$ 1.24
Flagellum	Very short, broad and blunt, approximately 1.2 mm	Very short, broad and blunt, 0.6 mm
PP/DP	Approximately 0.6	Approximately 3.3
Transition between PP and DP	Conspicuous annular constriction, situated proximally	Narrow medial region situated distally, without bottle-neck structure
Penial sheath	Thin, transparent, restricted to distal part of DP	Long; enveloping DP entirely and becoming extraordinarily thick medially
Internal ornamentation	7–8 papillar rows passing into 5–6 pleats, proximally branched/anastomosing	8–9 papillar rows, followed by 9–10 fine pleats, 6–7 larger pleats and a few jagged distal pleats

broader systematic comparisons, but its absence does not affect the species-level differentiation of *O. geminus* sp. nov. established here.

Multivariate analyses. The Principal Component Analysis (PCA) (Fig. 7, Table 2) revealed a well-defined morphometric structure among the eight analysed species. The first principal component (PC1) accounted for 66.77% of the total variance, whereas the second principal component (PC2) explained 20.46%, together representing 87.23% of the overall variation. PC1 was primarily associated with overall shell size, receiving the highest positive contributions from shell diameter (SD), shell height (SH), and umbilicus diameter (UD), whereas PC2 was largely determined by the number of whorls (NW).

Oxychilus geminus sp. nov. occupied a largely discrete region of morphospace and was clearly separated from *O. denatale*. It was also morphometrically distinguishable from the species historically assigned to *Hyalocornea*. Some overlap or proximity was observed among individual species in

Table 2. Loadings of the four z-standardised shell variables on the first two principal components obtained from the Principal Component Analysis. PC1 explains 66.77% and PC2 20.46% of the total variance, accounting together for 87.23%. Abbreviations: SD, shell diameter; SH, shell height; UD, umbilicus diameter; NW, number of whorls.

Variable	PC1	PC2
SD	0.5961	–0.1692
SH	0.5431	–0.0707
UD	0.4952	–0.3246
NW	0.3233	0.9279

the ordination space, but no attempt is made here to interpret the resulting pattern as evidence for the validity or boundaries of the historical subgeneric groups. The PCA is instead considered to support the distinct morphometric identity of *O. geminus* sp. nov. within the comparative dataset.

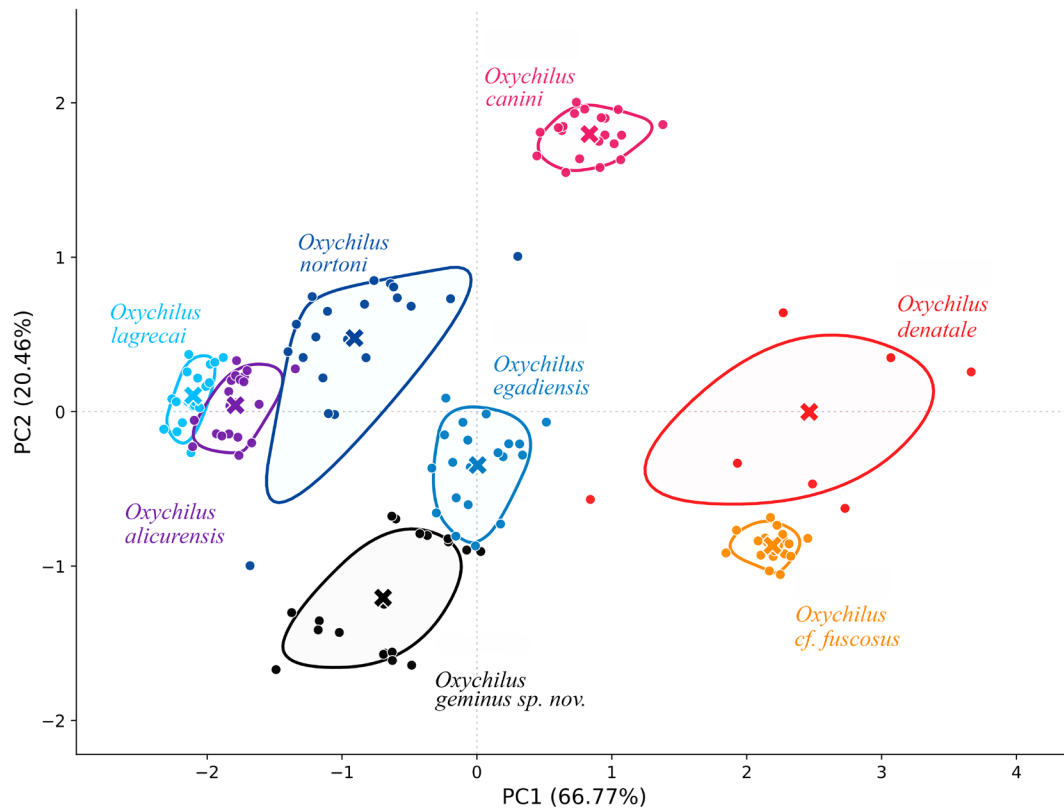


Figure 7. Principal Component Analysis (PCA) of eight Sicilian *Oxychilus* species based on four z-standardised shell variables (SD, SH, UD, and NW). PC1 explains 66.77% and PC2 20.46% of the total variance (cumulative variance = 87.23%). Points represent individual specimens, coloured crosses indicate species centroids, and smoothed convex hulls outline the occupied morphospace of each species. *O. egadiensis* (Favignana and Levanzo); *O. canini* (Monte Cofano); *O. nortoni* (Ustica); *O. alicurensis* (Alicudi); *O. denatale* (Marettimo); *O. geminus* sp. nov. (Montagna Longa); *O. cf. fuscus* (Monte Pellegrino); *O. lagrecai* (Filicudi).

The Linear Discriminant Analysis (LDA) (Fig. 8) provided stronger discrimination among the eight predefined species. The first two discriminant functions produced a nearly complete separation of the analysed taxa, with *O. geminus* sp. nov. occupying a clearly differentiated position in discriminant space. Leave-one-out cross-validation correctly classified 96.88% of the examined specimens (155 of 160), indicating a high discriminatory power of the four shell variables at the species level and providing further support for the morphometric distinctiveness of the new species. Because LDA is a supervised classification method based on predefined groups, the observed arrangement of species in discriminant space is not interpreted as evidence for subgeneric boundaries or phylogenetic relationships.

Taxonomic, evolutionary, and biogeographical considerations. The discovery of *Oxychilus geminus* sp. nov. provides an important new point of comparison with *O. denatale*, whose unusual shell and genital morphology has historically been associated with the genus-group name *Hyalofusca*.

Until now, the morphological characterisation of *Hyalofusca* has necessarily depended on *O. denatale* alone, making it impossible to distinguish characters peculiar to that species from those potentially informative at a broader systematic level. The discovery of a second species showing substantial morphological similarity to *O. denatale* therefore provides new comparative evidence but does not in itself demonstrate that the two species constitute a natural group.

Oxychilus geminus sp. nov. and *O. denatale* share a distinctive combination of shell and genital characters. Both possess a strongly depressed, tightly coiled, opaque-sericeous shell with numerous slowly increasing whorls and fine granulate microsculpture, together with a well-developed vaginal gland, a very short and broad flagellum, a conspicuous penial sheath, and proximal penial ornamentation composed of rows of papillae passing distally into longitudinal pleats. This overall concordance demonstrates a substantial morphological affinity between the two species.

None of these shared characters, however, can presently be demonstrated to represent an exclusive synapomorphy

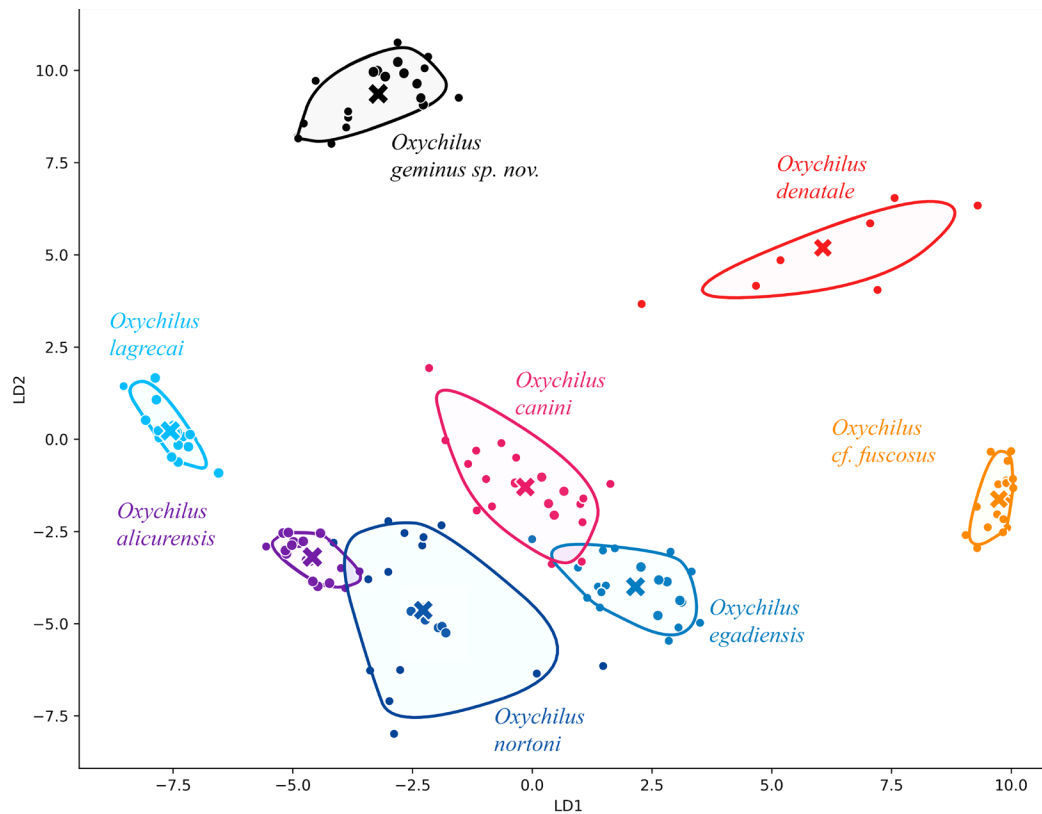


Figure 8. Linear Discriminant Analysis (LDA) based on four z-standardised shell variables (shell diameter, SD; shell height, SH; umbilicus diameter, UD; and number of whorls, NW) for eight Sicilian species of *Oxychilus*. Points represent individual specimens, coloured crosses indicate species centroids, and smoothed convex hulls outline the occupied discriminant space of each species. Leave-one-out cross-validation correctly classified 96.88% of the analysed specimens. *O. egadiensis* (Favignana and Levanzo); *O. canini* (Monte Cofano); *O. nortoni* (Ustica); *O. alicurensis* (Alicudi); *O. denatale* (Marettimo); *O. geminus* sp. nov. (Montagna Longa); *O. cf. fuscus* (Monte Pellegrino); *O. lagrecai* (Filicudi).

supporting *Hyalofusca* as a natural group. Polygyrate shells also occur in taxa historically assigned to *Hyalocornea*, granulate shell sculpture is present in several other Mediterranean Oxychilinae, and papillose-to-pleated internal penial ornamentation forms part of the broader anatomical variation occurring within *Oxychilus*. Manganelli *et al.* (2007) likewise emphasised that several conspicuous features of *O. denatale* occur independently in other oxychiline taxa and explicitly refrained from interpreting these similarities as evidence of phylogenetic relationships. Accordingly, the present evidence does not provide a defensible morphological diagnosis of *Hyalofusca* as a natural group.

This problem is not restricted to *Hyalofusca*. Riedel (1973) regarded *Hyalocornea* as only weakly differentiated from *Oxychilus* s. str., noting that its genital anatomy and internal penial ornamentation did not differ fundamentally from those of the nominotypical subgenus. Its recognition was based largely on the depressed, polygyrate shell and on the geographical coherence of the western Sicilian and cir-

cum-Sicilian taxa assigned to it. By contrast, *O. denatale* was interpreted as a more isolated morphological entity and was tentatively considered to show possible affinities with North African Oxychilinae. These historical interpretations remain of interest, but they do not constitute evidence that *Hyalofusca*, *Hyalocornea*, or the other genus-group taxa introduced by Monterosato represent morphologically coherent or monophyletic groups.

A formal reassessment of these historical genus-group taxa would therefore require a study specifically designed for that purpose. Such an analysis should include broad taxon sampling across the species historically assigned to *Hyalofusca*, *Hyalocornea*, and *Hyalofulgida*, together with representatives of *Oxychilus* s. str.; quantitative shell morphometrics analysed using multivariate methods; comparative genital and radular anatomy; and, ideally, molecular phylogenetic data. Particular attention should also be given to the identity of the nominal taxa originally associated with Monterosato's groups, including the poorly understood

aegusina from Favignana. Until such evidence becomes available, neither the morphological coherence nor the phylogenetic validity of these historical genus-group taxa can be considered established.

The comparison between *O. geminus* sp. nov. and *O. denatale* is nevertheless informative because it shows that some of the most conspicuous anatomical peculiarities of *O. denatale* are not shared by the new species. *Oxychilus geminus* differs markedly in shell size, number of whorls, configuration of the peripheral keel, relative width of the umbilicus, length and shape of the duct of the bursa copulatrix, epiphallus length, proportions of the proximal and distal penis, and extent of the penial sheath. In particular, its much shorter epiphallus, proximal penis shorter than the distal penis, conspicuous constriction between the two penial regions, and thin penial sheath restricted to the distal portion of the distal penis demonstrate that the extraordinarily long epiphallus, proximal penis much longer than the distal penis, and exceptionally thick and extensive penial sheath of *O. denatale* should primarily be regarded as species-specific specialisations rather than as characters diagnostic of a broader genus-group taxon.

The geographical separation between the morphologically similar *O. geminus* sp. nov. from mainland western Sicily and *O. denatale* from Marettimo Island is nevertheless biogeographically noteworthy. Their distributions raise the possibility that the observed morphological resemblance may reflect common ancestry, retention of ancestral morphological features, or convergence. In the absence of phylogenetic evidence, these alternatives cannot presently be distinguished, and the geographical pattern should therefore not be used to reconstruct the former distribution of a hypothetical shared lineage.

The carbonate massifs of north-western Sicily may have provided long-term refugia for localised terrestrial gastropod populations. Their topographical complexity, karstic structure, and discontinuous humid microhabitats are likely to favour persistence and isolation over long periods. The apparent association of *O. geminus* sp. nov. with deep limestone block fields and the superficial subterranean environment further suggests that poorly explored scree systems may harbour additional narrowly distributed oxychiline taxa.

The historical processes responsible for the present distributions of *O. geminus* sp. nov. and *O. denatale* remain uncertain. Palaeogeographical changes in the western Mediterranean, fragmentation of carbonate habitats and repeated episodes of geographical isolation between western Sicily and the Aegadian Islands may have contributed to the dif-

ferentiation of terrestrial gastropod faunas in this region. However, the available morphological and geographical evidence does not permit discrimination among common ancestry followed by vicariance, dispersal, retention of ancestral morphological traits, or independent morphological convergence.

Accordingly, we refrain from assigning *O. geminus* sp. nov. to *Hyalofusca*. The present evidence strongly supports the species-level distinctness of *O. geminus* and demonstrates a notable morphological affinity with *O. denatale* but does not establish that the two species constitute a natural subgeneric group. Comparative anatomical information remains incomplete for several Sicilian *Oxychilus*, and the systematic validity, limits and phylogenetic relationships of *Hyalofusca*, *Hyalocornea*, and *Hyalofulgida* remain untested. A dedicated future study integrating broader taxon sampling, quantitative shell morphometrics, genital and radular anatomy, and molecular phylogenetic evidence will be required to reassess these historical genus-group taxa.

Distribution. *Oxychilus geminus* sp. nov. is currently known only from its type locality on the eastern slope of Montagna Longa, near Carini (Palermo Province, north-western Sicily), where it has been recorded between approximately 500 and 650 m a.s.l. Despite repeated and spatially structured field surveys extending to the surrounding carbonate sectors of the Palermo Mountains, no additional populations have so far been discovered. The species therefore appears to have a highly restricted distribution, although its apparent association with deep limestone block fields and the superficial subterranean environment (Milieu Souterrain Superficiel, MSS) suggests that additional populations may remain undetected in similar habitats elsewhere within the carbonate massifs of north-western Sicily.

Habitat and Ecology. *Oxychilus geminus* sp. nov. is currently known exclusively from extensive limestone block fields forming large colluvial scree deposits along the eastern slope of Montagna Longa (Carini, Palermo), between approximately 500 and 650 m a.s.l. All living specimens and empty shells were recovered exclusively from the basal portion of these screes, within the transition zone between the lowermost limestone blocks and the residual soil accumulated beneath them. Living individuals were found only deep within the interstitial voids beneath several superimposed layers of limestone rocks and debris, probably close to or within the aphotic portion of the superficial subterranean environment (Milieu Souterrain Superficiel, MSS). Despite repeated and intensive surveys throughout the surrounding carbonate areas, no specimens were recovered outside this

highly localised microhabitat, indicating a strong ecological dependence on the environmental conditions provided by these deep scree systems.

Living individuals have so far been observed only during the winter months, immediately following periods of intense rainfall, when increased humidity apparently allows them to approach the upper layers of scree. During the dry season the species presumably retreats into deeper, thermally stable and permanently humid portions of the interstitial network, where it probably spends most of its life cycle.

The very pale, weakly pigmented body, together with the markedly reduced ocular spots and the apparent restriction to deep interstitial limestone habitats, are consistent with a troglomorphic mode of life and may indicate an evolutionary trend towards increased subterranean specialisation. Nevertheless, the available evidence is insufficient to regard the species as truly troglomorphic, and further ecological investigations will be necessary to clarify the degree of dependence of *O. geminus* sp. nov. on the MSS.

The type locality differs markedly from nearby scree systems, including those of Monte Pecoraro, which have been the subject of targeted malacological investigations but have yielded no specimens of the new species. Unlike these more exposed deposits, the inhabited scree remains protected from direct afternoon solar radiation and, together with its relatively high elevation, probably maintains the cool and humid microclimatic conditions required by the species. The apparent restriction of *O. geminus* sp. nov. to a single scree system therefore suggests that its distribution is controlled less by the general presence of limestone substrates than by the occurrence of very specific MSS microhabitats providing suitable thermal and hygrometric stability.

During visual surveys, *O. geminus* sp. nov. was found syntopically with *Acicula benoiti* (Bourguignat, 1864), *Acicula occidentalis* Reitano, Viviano, Sparacio & De Mattia, 2025, *Cochlostoma* sp. aff. *paladilhianum* (Saint-Simon, 1869), *Siciliaria* cf. *alcamoensis* R.A. Brandt, 1961, *Papillifera papillaris affinis* (R.A. Philippi, 1836), *Vitrea* sp., *Pomatias elegans* (O.F. Müller, 1774), *Deroceras* cf. *panormitanum* (Lessona & Pollonera, 1882), and *Milax* cf. *gagates* (Draparnaud, 1801). Particularly noteworthy are *Campylaea macrostoma* (Ross-mässler, 1837), occurring beneath the scree at shallower depths, and *Acicula benoiti*, recovered exclusively by sieving the fine residual soil accumulated between the limestone blocks.

The superficial subterranean environment has attracted increasing attention in recent years owing to the discovery of numerous narrowly endemic terrestrial gastropods with cryptic ecological requirements. Once largely overlooked

during traditional malacological surveys, the MSS is now recognised as a network of interstitial voids and fissures within screes and block fields characterised by remarkably stable temperature and humidity conditions, acting as an important refuge for specialised land-snail assemblages. Recent discoveries of MSS-associated taxa, including *Sardopoiretia emanueli* Bodon, Nardi, Braccia & Cianfanelli, 2010, *Hypnecarnica micaelae* Cianfanelli & Bodon, 2018, the Sicilian endemics *Schileykiella mariarosariae* R. Viviano, A. Viviano, Liberto, Reitano & Sparacio, 2019 and *Ferussacia antoninii* R. Viviano, A. Viviano, De Mattia, Reitano & Sparacio, 2025, further emphasise the importance of these habitats as poorly explored refugia harbouring highly specialised and often narrowly endemic molluscan lineages. The ecology of *O. geminus* sp. nov. provides additional evidence that the Mediterranean MSS represents an overlooked hotspot of terrestrial gastropod diversity and suggests that further targeted investigations of deep limestone screes in Sicily will likely reveal additional narrowly endemic taxa.

Status and conservation. *Oxychilus geminus* sp. nov. is currently known from a single, spatially restricted locality on a limestone mountain in north-western Sicily. Despite targeted surveys covering approximately 0.41 km² of apparently suitable surrounding habitat, the species was found only at one highly localised site. Its actual occupied habitat is therefore likely to be considerably smaller than the surveyed area. Using the standard IUCN 2 × 2 km grid, the Area of Occupancy is estimated at 4 km². The Extent of Occurrence cannot be calculated geometrically from a single occurrence point and is therefore conventionally estimated as equal to the AOO, namely 4 km².

The species occurs at a single location, defined by the principal threats affecting its only known population. Its habitat consists of deep limestone block deposits associated with mobile depositional cones descending from the mountain summit. These deposits are subject to continuing natural displacement and instability. In addition, the entire area is affected by cattle, sheep, and goat grazing. Livestock trampling and grazing are inferred to cause continuing deterioration of habitat quality through substrate compaction, displacement of stones and superficial debris, reduction of vegetation and litter cover, and alteration of the cool and humid interstitial microhabitats occupied by the species.

Because the species has an EOO of approximately 4 km², an AOO of 4 km², occurs at a single location, and is undergoing an inferred continuing decline in the quality of its habitat, it is assessed as Critically Endangered under criteria B1ab(iii)+2ab(iii).

CONCLUSIONS

The discovery of *Oxychilus geminus* sp. nov. represents a significant addition to the diversity of Sicilian Oxychilidae. The new species is unequivocally distinguished from *O. denatale* by a coherent combination of conchological and genital anatomical characters, while showing a notable overall morphological resemblance to the Marettimo endemic.

Comparison between the two species also demonstrates that several of the most conspicuous anatomical peculiarities of *O. denatale*, including its extraordinarily long epiphallus, the predominance of the proximal over the distal penis, and its exceptionally thick and extensive penial sheath, should primarily be regarded as species-specific specialisations rather than as diagnostic features of a broader genus-group taxon. Conversely, the characters shared by *O. geminus* sp. nov. and *O. denatale* cannot presently be demonstrated to represent exclusive synapomorphies supporting their inclusion in a natural group corresponding to *Hyalofusca*.

We therefore refrain from formally assigning *O. geminus* sp. nov. to *Hyalofusca* or to any other subgenus. This conservative treatment is consistent with the caution expressed by Manganelli *et al.* (2007), who considered the phylogenetic significance of the characters observed in *O. denatale* unresolved and postponed assessment of the status of *Hyalofusca* pending broader comparative evidence. The present study supports a substantial morphological affinity between *O. geminus* and *O. denatale* but does not establish that this resemblance reflects a close phylogenetic relationship.

The geographical separation of the two morphologically similar species, with *O. geminus* sp. nov. occurring on mainland western Sicily and *O. denatale* on Marettimo Island, is nevertheless biogeographically noteworthy. Whether this pattern reflects common ancestry followed by geographical isolation, retention of ancestral morphological features, dispersal, or convergence cannot presently be determined.

A formal reassessment of *Hyalofusca* and the other historical genus-group taxa proposed for Sicilian polygyrate *Oxychilus* should therefore be undertaken separately, using broader taxon sampling, quantitative shell morphometrics, comparative genital and radular anatomy, and molecular phylogenetic evidence. Until such evidence becomes available, the morphological resemblance between *O. geminus*

sp. nov. and *O. denatale* should be regarded as a well-documented comparative observation rather than evidence for a demonstrated subgeneric or phylogenetic relationship.

ACKNOWLEDGEMENTS

We are grateful to Roberto Viviano and Ignazio Sparacio (Palermo, Italy) for their valuable assistance during the fieldwork. We are particularly grateful to Bernhard Hausdorf and David Cilia for their essential advice and valuable comments, which greatly contributed to improving the manuscript. The first author also wishes to thank Jessica Macor (Noto, Italy) for her assistance in the field and for her constant support throughout this study.

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Manuscript submitted: 27 July 2026

Revised manuscript accepted: 17 September 2026

Editor: Robert Forsyth